Forage Res., **44** (4) : pp. 224-229 (2019) **http://forageresearch.in**

AGRONOMY- A KEY TO INFLUENCE FODDER TOXIC SUBSTANCES–A REVIEW

HARPREET KAUR OBEROI* AND MANINDER KAUR

Forage and Millet Section, Department of Plant Breeding and Genetics
Punjab Agricultural University, Ludhiana
**(e-mail : harpreetoberoi@pau.edu)*

(Received : 18 March 2019; Accepted : 30 March 2019)

SUMMARY

Fodder crops quality depends on the toxic substances present in it. The three main toxic substances *viz.* nitrate, oxalate and HCN are most important and are present in different fodder crops and the appropriate agronomic management strategies which have the potential to increase the green fodder yield also has the potential to improve the fodder quality by influencing these most common toxic elements. The influence of agronomy on these negative impact nutrients in various fodder have been discussed. The fertilization application of nitrogen in split doses provides better nutrient distribution and reduces the potential for nitrate toxicity whereas the increase nitrogen application and unirrigated conditions resulted in increase in nitrate but well under toxic level. The form of fertilization also alters the antinutrients levels such as FYM with phosphate fertilizer resulted in lower nitrate content in berseem. Sowing time showed variation in oxalate level in Napier Bajra hybrid. Similarly, sowing of sorghum in also influenced the HCN production. Therefore, the agronomy is found to be the key to improve forage quality by changing content of antinutrients along with yield by adopting appropriate agronomic practices from seed sowing till harvesting.

Key words : Fodder crops, toxic traits, agronomic practices, antinutrients

India supports nearly 20 per cent of the world's livestock being the leader in cattle (16%) and buffalo (5.5%) population. Deficiency in feed and fodder has been identified as one of the major components in achieving the desired level of livestock production. The shortage in dry fodder is 21.8 per cent compared with requirement of 560 million tonnes for the current livestock populations (Rana *et al.*, 2013). For better efficiency of livestock, only quantitative production is not important, but the quality also plays its role.

The feeding value of any forage is a function of a number of characteristics of the species, including its availability, accessibility, nutrient availability, chemical composition and presence or absence of anti-nutritional factors. Any forage material that does not provide nutrients adequate for growth or milk productions, however, in its looks, smells, protein or fiber contents, it is not good quality forage. The feeding value of forage crops depends on the presence of anti-quality components (Adesogan *et al.*, 2006). Many factors influence forage quality. However, forage quality varies greatly among and within forage crops, and nutritional needs also vary among and within animal species and classes. The most important are forage species, stage of maturity at harvest, and (for stored forages) harvesting and storage methods. Secondary factors include soil fertility and fertilization, temperatures during forage growth, and variety.

Therefore, the anti-nutritional contents of a forage crops could be manipulated by agronomic management practices to reduce the opportunity for toxicity and agronomic techniques are also known to be helpful to obtain higher productivity of good quality herbage to fulfill feeding requirement of dairy animals.

Common anti-nutritional factors of forage crops

Anti-nutrients or anti-nutritional factors are secondary metabolites, shown to be highly biologically active and may be defined as those substances generated in natural feedstuffs by the normal metabolism of species and by different mechanisms (for example inactivation of some nutrients, diminution of the digestive process or metabolic utilization of feed) which exerts effect contrary to optimum nutrition. Anti-nutritIonal factors interfere with feed utilization and affect the health and production of animal or they act to reduce nutrient intake, digestion, absorption and utilization and may produce other adverse effects. The major ones include: nitrates, oxalates, HCN. More often than not, a single plant may contain two or more toxic compounds (Akande *et al.*, 2010).

Nitrate

Nitrate toxicity of cattle was noted as early as 1895 with corn-stalk poisoning. However, nitrate was not recognized as the principle toxicant during that period. In the late 1930s, after an outbreak of oat-hay poisoning in the high plains region, an indictment of nitrate was finally made (Launchbaugh, 2001). Some of the fodder crops such as sudan grass, pearl millet and oats can accumulate nitrate at potentially toxic levels. Nitrate poisoning is better described as nitrite poisoning. When livestock consume forages, nitrate is normally converted in the rumen from nitrate to nitrite to ammonia to amino acid to protein. Nitrate concentrations are usually higher in young plants and decrease as plants mature. Most of the plant nitrate is also located in the bottom third of the stalk, hence the leaves contain less nitrate and the flowers or grain contain little to no nitrate (Singh *et al.*, 2000).

Under normal growth conditions, there is little nitrate build up, even though plant roots are absorbing large amounts of nitrate, because protein conversion keeps pace with root absorption. However, in certain conditions, this balance can be disrupted so that the roots will accumulate nitrate faster than the plant can convert the nitrate to protein. Abnormal growing conditions such as drought, frost, unseasonable or prolonged cool temperatures, hail, shade, disease, high levels of soil nitrogen, soil mineral deficiencies or herbicide damage can cause high nitrate accumulation in forages.

When forages have an unusually high concentration of nitrate, the animal cannot complete the conversion and nitrite accumulates. Nitrite is absorbed into the bloodstream directly through the rumen wall and converts haemoglobin (the oxygen carrying molecule) in the blood to met-haemoglobin, which cannot carry oxygen. The blood turns to a chocolate brown color rather than the usual bright red. An animal dying from nitrate (nitrite) poisoning dies from asphyxiation, or lack of oxygen. Factors affecting the severity of nitrate poisoning are the rate and quantity of consumption, type of forage, energy level or adequacy of the diet (Benjamin, 2006).

Oxalate

Strong bonds are formed between oxalic acid, and various other minerals, such as Calcium, Magnesium, Sodium, and Potassium. This chemical combination results in the formation of oxalate salts. Oxalate is an anti-nutrient which under normal conditions is confined to separate compartments. However, when it is processed and/or digested, it comes into contact with the nutrients in the gastrointestinal tract. When released, oxalic acid binds with nutrients, rendering them inaccessible to the body. If excessive amount of oxalic acid is consumed regularly, nutritional deficiencies are likely to occur, as well as severe irritation to the lining of the gut (Habtamu and Negussie, 2014).

Guinea grass, bajra and Napier bajra hybrid contain oxalate content within safe limits, however, they may prove toxic if fed over for extended period of time. Oxalates react with calcium to produce insoluble calcium oxalate, reducing calcium absorption. This leads to a disturbance in the absorbed calcium: phosphorus ratio, resulting inmobilization of bone mineral to alleviate the hypocalcemia (Rahman and Kawamura, 2011).

Cyanogens

Cyanogens are glycosides of a sugar or sugars and cyanide containing aglycone. It can be hydrolysed to release HCN by enzymes that are found in the cytosol. The HCN is absorbed and is rapidly detoxified in the liver by the enzyme rhodanese which converts CN to thiocyanate (SCN). Excess cyanide ion inhibits the cytochrome oxidase. This stops ATP formation, tissues suffer energy deprivation and death follows rapidly (Sarah, 2007).

Prussic acid poisoning can occur when livestock are pastured on sorghum type plants, including grain sorghum, forage sorghum, sudangrass etc. Prussic acid causes asphyxiation by inhibiting the action of the enzyme that links oxygen with red blood cells (Allison, 2002). Ruminants are more susceptible than non ruminants. HCN level will be high in young seedlings rather than in matured seedlings.

Agronomic practices to minimize anti-quality components

The significant increase in Nitrate-N content when grown under tree shades was observed in Napier Bajra hybrid which is considered an anti-quality character in fodder crops. Conversion of nitrates to amino acids and proteins is linked closely with photosynthesis. Light is the energy source for these activities, so shaded plants or lower leaves may be higher in nitrates than plants grown in full light. Silage preparation of fodder crops also reduces nitrate levels in ensiled crops by 40 to 60% due to fermentation. Delay harvesting of immature crops following drought if conditions might favor further growth and grain development. Harvesting close to maturity is advised to reduce the risk of nitrate toxicity.

In general, application of excessive amount of nitrogenous fertilizers leads to accumulation of nitrates in plants. Singh *et al.* (2000) studied the effect of application of different levels of nitrogenous fertilizers on the accumulation of nitrate in the oat fodder. The oat crop was grown in two groups. Four levels of nitrogen fertilizer were applied in two and three splits in each group. From both the groups, the fodder was harvested first at 70 days after sowing and the second cut was taken at 50 per cent flowering stage. The results indicated that the concentration of nitrate-N was higher with two splits compared to three splits at each level of nitrogen application. All the values of nitrate-N decreased markedly when the crop was harvested at 50 per cent flowering. The above findings showed that each level of nitrogen fertilizer applied in three splits was quite safe from toxic levels of nitrates even during the early stages of fodder growth. Split nitrogen application provides better nutrient distribution and reduces the potential for toxicity.

TABLE 1
Effect of N application on NO_3-N (ppm) content and economics of multicut oats (Mean of 4 years)

N-levels (kg/ha)		NO_3-N (ppm)		Economics
Cut-1	Cut-2	1st cut	2nd cut	B : C ratio
75	0	603	94	1.53
75	25	604	117	1.68
75	50	601	134	1.74
75	75	602	141	1.72

(Singh *et al.*, 2000).

Similarly, Singh *et al.* (2000) noticed decrease in nitrate content at second cut and the benefit to cost ratio (B:C) was found to be 1.74 with 75 Kg/ha (Ist cut) and 50 Kg/ha (IInd cut) nitrogen fertilization from the mean of four years data (Table 1) in multicut oats. In another study, split dose of 80 Kg/ha nitrogen fertilization given before each cut in oats at 70 DAS noticed to accumulate nitrate quite below the toxic level (Fig. 1).

Further studies on the different plant portions

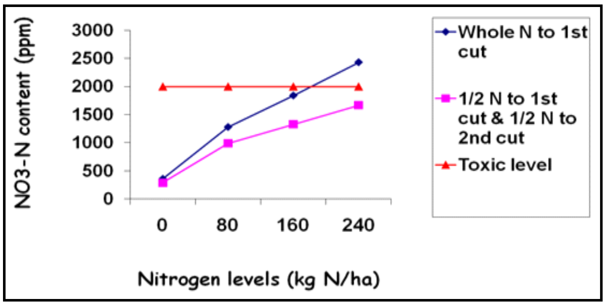

Fig. 1. Effect of nitrogen levels on the NO_3-N content in oats at 70 DAS.

of oats were analysed for nitrate content after the application of 240 Kg/ha nitrogen fertilizer at two harvest stages i.e. 90 DAS and flowering. In comparison to lower, mid and whole stem portion, the upper stem portion noticed to have lower content of nitrate. The nitrate level in leaves was the lowest. However, harvest at flowering stage resulted in lower nitrate accumulation in all plant portions. In bajra, nitrogen fertilization at 150 Kg/ha rate showed similar trend in nitrate accumulation in different plant portions as seen in oats and partial irrigation condition resulted in more nitrate content than under normal irrigation condition (Tiwana *et al.*, 2012) (Table 2).

TABLE 2
NO_3-N con. (ppm) in different plant parts of bajra-150 kg N/ ha

Plant parts	Normal irrigation	Partial irrigation	Mean
Leaves	530	616	573
Whole plant	910	1054	982
Stem	1290	1498	1394
a) Upper stem	930	1080	1005
b) Middle stem	1150	1456	1303
c) Lower stem	1780	1965	1873
Mean	1098	1278	-

In berseem, 25 Kg N + 75 Kg P_2O_5/ha or 15t FYM +50 Kg P_2O_5/ha are recommended fertilizer application before each cut and the nitrate level was noticed to be comparatively lower in 15t FYM +50 Kg P_2O_5/ha fertilizer application (Table 3). Farmers along with basal dose add nitrogen to increase the yield but it leads to nitrate toxicity in berseem in both the cuts. Further, increasing nitrogen level led to increase in nitrate content in berseem. (Tiwana *et al.*, 2012.)

In bajra, the effect of nitrogen and irrigation showed that at 100 Kg N/ha application and in irrigated condition the nitrate level was much lower compared to its toxicity level (Fig. 2). However, under unirrigated condition the content of nitrate was higher than in

TABLE 3
Effect of N-levels on NO_3-N (ppm) in berseem fodder

N-levels (kg N/ha)	25 kg N+75 kg P_2O_5/ha		15 t FYM+50 kg P_2O_5/ha	
In addition to basal dose	1st cut (2 Jan.)	2nd cut (7 Feb.)	1st cut (2 Jan.)	2nd cut (7 Feb.)
0	560	466	532	424
25	942	578	660	506
50	1106	680	774	582
75	1362	837	955	698
Mean	1043	640	730	553

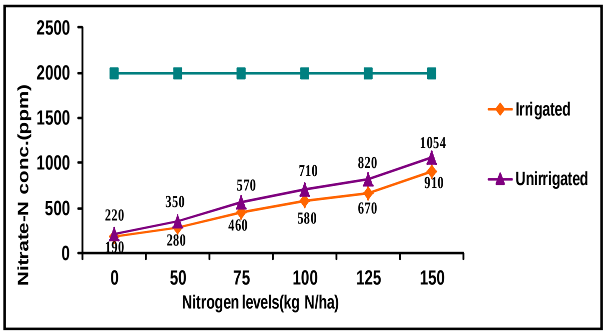

Fig. 2. Effect of nitrogen and irrigation on the nitrate (ppm) of bajra.

irrigated condition and with increase in nitrogen resulted increase in nitrate under both conditions (Tiwana *et al.*, 2012).

Young plants contain more oxalate than older plants. During early stages of growth, there is a rapid rise in oxalate content followed by a decline in oxalate levels as the plant matures. Plant tissue obtained in the early summer exhibited higher oxalate content compared to similar samples obtained later in the season. It is also reported that leaf and stem tissues obtained in the early summer exhibited nearly equivalent levels of oxalate (Rahman *et al.*, 2006). As the season advanced, the oxalate content in leaf tissue decreased gradually, whereas the decrease was more rapid in the stem tissue. It has been observed that the oxalate content of Napier grass can be manipulated by varying the harvesting interval, and that oxalate content declined as the harvest interval increased (Smitha *et al.*, 2013).

The oxalate content in the silage of Napier bajra hybrid sown at different dates was analysed by Kaur *et al.* (2016) (Table 4). The Napier bajra hybrid sown in month of August was noticed to have lower oxalate content compared to that sown in months from April to July.

Rahman *et al.* (2008) who observed that N fertilization with urea either had no effect on the accumulation or even reduced the level of soluble

TABLE 4
Oxalate content (%) in NBH

Month	Green forage	Silage
April	2.10	0.46
May	2.18	0.45
June	3.64	0.56
July	3.17	0.44
August	2.61	0.33

(Kaur *et al.*, 2016).

oxalate. Further, Rahman (2009) has shown that nitrate treated Napier grass contained significantly higher soluble oxalate content than ammonium treated Napier grass. It seems that oxalate accumulation in Napier grass may be affected by form of N application. The medium level (300 kg/ha) of N and low level (150 kg/ha) of K produced comparatively lower content of soluble oxalate without resulting in lower DM yield.

Pandey *et al.* (2011) observed that significantly decreasing trend in HCN content was observed with the advancement in the plant growth. It was higher in hybrid varieties like CSH-17 as compared to local sorghum variety. HCN content is reduced to non-toxic level after 45-50 days of sowing in most of the varieties of sorghum fodder. It was, therefore, concluded that green sorghum fodder can be fed safely after 45-50 days of sowing or at any stage of growth after drying. Harvesting of forage sorghum at 50% flowering stage yields the best quality forage with minimum HCN contents.

Saini *et al.* (2013) noticed that drought of four weeks before harvesting increased HCN content in comparison to three, two- and one-week drought. This increase in HCN with increase in nitrogen levels was observed in all four drought conditions in sorghum. In another study by Singh (2018), the effect of different dates of sowing and different irrigation regimes (normal, partial and unirrigated) in sorghum on HCN content was seen. The sowing of sorghum in last week of May (after 25^{th} May) and two irrigations had led to lower HCN formation and higher green fodder yield when harvested at 45 DAS (Table 5).

The application of sulfur fertilizer decreased the concentration of hydrocyanic acid and nitrate uptake. Ration digestibility of livestock increased markedly as the S content of dry matter was raised. Proper S fertilization will minimize the changes of toxic levels of NO_3– N accumulation in fodder crops (Beaton, 1972).

Similarly, Singh *et al.* (1983) studied that the

TABLE 5
Interaction effect of sowing dates and irrigation on HCN (ppm) content of sorghum (45 DAS)

Sowing dates	Irrigation levels		
	Normal	Partial	No irrigation
April 10	85	113	127
April 20	74	102	108
April 30	62	84	91
May 10	56	78	88
May 20	38	57	71
May 30	32	42	50
CD-14			

(Singh, 2018. Thesis submitted to PAU).

combined application of 100 kg S and 50 kg P_2O_5 ha^{-1} is needed for the production of forage sorghum with a safe HCN contents. Maximum crude protein of 7.5%, sugar of 8.5% and fat of 2.5% observed at 50-100 kg P and S respectively. The HCN content in shoots decreased significantly due to P application and with the advancement of crop growth (Chand *et al.*,1992).

Patel *et al.* (2003) reported that application of P @ 40 kg/ha and 80 kg/ha enhanced the average green forage yield by 6.5 and 10.9 percent and crude protein yield by 4.4 and 14.6 per cent, respectively of sorghum over control. Moreover, application of P from 0 to 40 and 80 kg ha-1 significantly decreased HCN contents of leaf by 16.0 and 18.1 per cent, respectively over no application of P. Application of S @ 20 kg/ha was also observed to reduce HCN contents in leaf of sorghum by 10.5 and 32.7 per cent.

Bahrani and Deghani (2004) reported that the forage prussic acid percentage of the second cut was significantly lower than the first cut, probably due to degradation of the acid and a higher metabolic activity of the plant due to higher temperatures during growth processes which can reduce the prussic acid accumulation, these low amounts of FPAP (Forage Prussic Acid Percentage) are not toxic to animals.

Vijay *et al.* (1983) showed that fertilization of sorghum by sulphur and phosphorus reduced hydrogen cyanide (HCN) content of plant, increased herbage yield, herbage protein, sugar and fat content. Split application of nitrogen decrease the risk of prussic acid toxicity in fodder crops. Application of irrigation one week before harvesting and addition of P and S along with recommended nitrogen dose, minimised the HCN content than without P and S in fodder sorghum (Tiwana *et al.*, 2013).

It is concluded that the agronomy is one of the valuable key to improve forage quality in altering the content of antinutrients along with yield by adopting appropriate agronomic practices from seed sowing till harvesting.

REFERENCES

Adesogan, A. T., L. E. Sollenberger, and J. E. Moore, 2006 : Feeding value and anti-nutritive factors of forage. *Tree Legumes* pp. 174-179.

Akande, K. E. and E. F. Fabiyi, 2010 : Effect of Processing Methods on Some Anti-nutritional Factors in Legume Seeds for Poultry Feeding. *International J. Poultry Sci* **9** : 996-1001.

Allison, 2002. Prussic acid poisoning in Livestock. Guide B-808, www.cahe.nmsu.edu

Bahrani, M. J. and G. Deghani, 2004 : Summer forage sorghum yield, protein and prussic acid contents as affected by plant density and nitrogen top dressing. *J. Agric. Sci. Tech*. pp. 73-83.

Beaton, J. D., 1972 : Sulfur Status of the Middle Atlantic States. *Sulfur Inst. J.* **8** : 6-9.

Benjamin, D. N., 2006. Effects of fertilizer application and cutting interval on nitrate accumulation in bermudagrass. M.Sc. (Agri.), Thesis: Univ.Tennessee, Martin.

Chand, K., M. L. Dixit, and S. K. Arora, 1992 : Yield and quality of forage sorghum as affected by phosphorus fertilization. *J Ind. Soc. Soil Sci.* **40** : 302-306.

Habtamu, F. and R. Negussie, 2014 : Antinutritional factors in plant foods: Potential health benefits and adverse effects. *International J Nutr Food Sci* **3** : 284-289.

Kaur, R., M. Goyal, and U. S. Tiwana, 2016 : Influence of seasonal variation on oxalate accumulation in Napier Bajra hybrid under different nitrogen nutrition. *Range Mgmt. Agroforestry* **37** : 62-68.

Launchbaugh, K., 2001 : Risk management to reduce livestock losses from toxic plants. Fort Worth, TX: Grazing Lands Technology Institute.

Pandey, R. K., D. Kumar, and K. M. Jadhav, 2011 : Assessment of determinants for reducing HCN content in sorghum used for ruminant in Gujarat, India. Livestock Research for Rural Development, **23** , Article #66.

Patel, P. C., A. V. Kotecha, and J. P. Yadavendra, 2003 : Effect of phosphorus and sulphur nutrition on forage yield, nutrient uptake and yanide content of forage sorghum. *Ind. J. Agric. Chem.* **36** : 113-121.

Rahman, M. M., M. Niimi, Y. Ishii, and O. Kawamura, 2006 : Effects of season, variety and botanical fractions on oxalate content of napiergrass (Pennisetum purpureum Schumach). *Grassl. Sci.* **52** : 161-166.

Rahman, M. M. and O. Kawamura, 2011 : Oxalate accumulation in forage plants: some agronomic, climatic and genetic aspects. *Asian Aust. J. Anim. Sci*. **24** : 439-448.

Rahman, M. M., M. Yamamoto, M. Niimi, and O. Kawamura, 2008 : Effect of Nitrogen Fertilization on Oxalate Content in Rhodesgrass, Guineagrass and Sudangrass. *Asian Aust. J. Anim. Sci*. **21** : 214-219.

Rana, D. S., B. Singh, K. Gupta, A. K. Dhaka, and S. K. Pahuja, 2013 : Effect of fertility levels on growth, yield and quality of multi-cut forage sorghum (*Sorghum bicolor* L.) genotypes. *Forage Res.* **39** : 36-38.

Saini, A. and U. S. Tiwana, 2013 : Effect of irrigation and nitrogen levels on growth, yield and hydrocyanic acid (HCN) content of forage sorghum (*Sorghum bicolour*) under different cutting management. *Indian J. Ecol.* **40** : 40-42.

Sarah, R., 2007 : Prussic acid poisoning in Livestock. www.dpi.nsw.gov.au/ Prime facts.

Singh, A., U. S. Tiwana, M. S. Tiwana, and K. P. Puri, 2000 : Effect of application method of level of nitrogen fertilizer on nitrate content in oat fodder. *Ind. J. Anim. Nutr.* **17** : 315-319.

Singh J., 2018 : Fodder productivity and HCN content of hybrid sorghum in relation to sowing time and sulphur under different moisture regimes. Thesis submitted to PAU.

Singh, V., D. Singh, and D. A. Shinde, 1983 : S and P fertilization reduce HCN content of sorghum. *Sulphur Agric*. **7** : 12-14.

Smitha Patel, P. A., S. C. Alagundagi, and S. R. Salakinkop, 2013 : The anti-nutritional factors in forages - A review. *Current Biotica* **6** : 516-526.

Tadele, Y., 2015 : Important anti-nutritional substances and inherent toxicants of feeds. *Food Sci. Quality Mgmt.* **36** : 40-47.

Tiwana, U. S., A. Singh, and U. Rani, 2012 : Productivity, quality, nitrate-N and disease incidence in fodder pearl millet as influenced by irrigation and nitrogen levels. *Range Mgmt. Agroforestry* **33** : 69-72.

Vijay, S., S. Dwakika, and P. A. Shendida, 1983 : Sulfur and phosphorus fertilization reduces HCN contents of sorghum. *Sulfur in Agric.* **7** : 12-14.